JAPANESE TUNA SURVEYS IN TROPICAL WATERS

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EXPLANATORY NOTE

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Fish and Wildlife Service
Albert M. Day, Director

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JAPANESE TUNA SURVEYS IN TROPICAL WATERS

Translated from the Japanese language by

W. G. Van Campen

Pacific Oceanic Fishery Investigations

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1/ South Sea Fisheries [Nanyō Suisan], Vol. 7, No. 9, pp. 10-21 Published by the South Seas Fisheries Association, Inc. [Shadan Hōjin Nanyō Suisan Kyōkai] Sept. 25, 1941.

2/ From Science of the Seas [Kaiyō no Kagaku], Vol. 3, No. 10. October, 1943.

On the Search for Southern Tuna Fishing Grounds

[TN. This paper is taken from a journal of a semi-popular nature and is designed to give persons in the fishing industry a superficial acquaintance with the progress of scientific research. Too much reliance should not, therefore, be placed upon the accuracy of the statements and statistics contained in it.]

Introduction

Recently the South Seas fisheries have suddenly come to be regarded as a problem, and their importance is being emphasized along with the other problems of the South. The newest topic in the field of South Sea fisheries is the southern tuna fishery, and the heart of the South Seas fisheries problem is the remarkable development of the tuna fishery, particularly in equatorial waters. The southward expansion of the tuna fishery is not only an economic problem, arising from its promising character, but like the so-called North Pacific fisheries it also contains a good many political implications.

The South Seas tuna fishery in recent years

The promising nature of the South Seas tuna fishery and the rise in the price of fish in Japan have resulted in a sudden expansion, and the number of fishermen from Japan operating in the area has increased remarkably. The number of boats operating in South Sea Island waters during the past three years and the success which they have achieved may be roughly indicated as follows.

Year	Number of Boats	Number of Trips	Value of Catch	Notes
1938	39	149	1,600,000 ¥	Oct. 1938 to Mar. 1939 winter season
1939	58	187	3,545,970 ¥	July 1939 to June 1940
1940	226	226 [?sic]	5,944,480 ¥	January to December 282,124 fish

An examination of the registry of boats operating in the South Seas fishery by prefectures shows the following results. The majority of the boats have their primary base at Misaki in Kanagawa Prefecture.

Kanagawa Prefecture, Mie Prefecture, Fukushima Prefecture, Miyagi Prefecture, Iwate Prefecture, Aomori Prefecture, Yamagata Prefecture, Akita Prefecture, Chiba Prefecture, Tōkyō District, Aichi Prefecture, Kōchi Prefecture, and Tokushima Prefecture.

Last year, in view of the promise shown by the South Seas fishery, some thought was given to an expansion by the Japanese tuna canning industry into the area. It was even thought that such a development might take place immediately as a means by which the Japanese canning industry could

escape from the difficult situation in which the scarcity and high price of fish in Japan had placed it. An example of the advance of the processing industry into the area is the establishment of a cannery in April of this year by the East Indies Fisheries Company [Tō Indo Suisan Kabushiki Kaisha] (with main offices at Palau) at Bitong (near Menado) in Celebes in Dutch territory.

Thus the tuna fishery of the South Seas has been making great forward strides during the past two or three years. The author has been in the area since 1932 and has had an opportunity to take part in investigations of fisheries and particularly of the tuna fishery in the Marianas, Carolines, Marshalls, Sulu Sea, Celebes Sea, Flores Sea, Banda Sea, and the Arafura Sea. Among these various areas those about which the present investigations of South Seas tuna fishing grounds are centered are the tuna grounds which lie near the Equator. The following information is here recorded as reference data for the investigation and study of these grounds. If the data should serve as a guide in the investigation of the southern tuna grounds, the author will be very happy.

Equatorial Tuna Grounds

Areas where the tuna congregate

(I) Good fishing grounds from the point of view of currents (form of water systems)

As stated above, the tuna fishery is the bright star of the fisheries world and is a main subject of discussion, but it is often not made clear whether the tuna referred to is the big-eyed, the albacore, the yellowfin, or the spearfish. Naturally the fishing grounds are different depending on the species. When the South Seas tuna grounds are spoken of, one can usually tell which species is meant because of the fact that in the vicinity of the Equator the yellowfin occurs in the greatest abundance. This species will therefore be made the object of our discussion here, and when the word "tuna" is used in the following pages the yellowfin tuna is meant.

In equatorial waters the tuna grounds are comparatively numerous in the area from about 7 - 8° north latitude to around 8° South. The northern limit is in the vicinity of the northern boundary of the Northern Equatorial Current. The accompanying chart of Catch Density and Oceanographic Conditions on South Sea Tuna Grounds (Chart 1) shows the data which have been gathered and examined for the grounds which have been most active up to the present time. In simple terms we can answer the question of where the tuna of the South Seas congregate by saying that they are most abundant in the Equatorial Counter-current.

If it is asked where within the Counter-current the best catches are made, we can recognize the following types of areas as good fishing grounds by the form of the current area.

1. The outer edges of bends in the Equatorial Counter-current
   For example, the fishing grounds southeast of Palau

2. Where currents meet and intermingle
   For example, the waters northeast of Halmahera (discovered by the Zuihō Maru in March 1941), Fishing Ground C, part of Fishing Ground D
3. At the ends of branches of the Counter-current
   For example, the coastal waters east of Palau
4. Where the Counter-current system is narrow
   For example, the waters 600 miles south of Saipan. Fishing Ground A. Fishing Ground B.
5. Where oceanographic conditions are favorable along the edges of the Counter-current
   For example, the waters 300 miles south of Palau. Fishing Ground G. The waters 150 miles south of Jaluit (discovered by the Zuihō Maru in November 1940). The waters 300 miles southwest of Ponape (discovered by the Zuihō Maru in November 1940).

The above is a general explanation from the point of view of the form of the current area of the Counter-current. The locations of the grounds can thus be found on the North Pacific Current Chart (published by the Hydrographic Office), but it goes without saying that they are always changing, and such locations as the outer edges of bends in the current area (water system) can easily shift. Consequently it is necessary to proceed to the area and then make a test set of the longline in order to determine the direction of the current. For example, a place where a southeasterly current turns to the northeast or vice versa can be assumed to be a bend in the current.

(II) Good fishing grounds from the point of view of oceanographic conditions (sea conditions)

The good fishing grounds as defined by the form of the current are of course included in the good fishing grounds defined from the point of view of oceanographic conditions, but the former have been described separately above in order to facilitate the reader's understanding of the subject. The author will now explain good fishing grounds from the point of view of oceanographic factors on the basis of the results of investigations which have been made in the past, the data from which he has at hand. The good fishing grounds described above are naturally characterized by these favorable oceanographic factors.

1. Velocity of the current

Within the Equatorial Counter-current the most suitable velocities are from 0.5 to 1.0 knot. Few fish are taken in water systems which have excessively slow speeds of less than 0.5 knot or in strong currents of over 1.5 knots.

On this score the aforementioned Fishing Ground F, which is located southeast of Palau on the outer side of a bend in the Equatorial Counter-current, is a good fishing ground. Of course it also exhibits the other favorable oceanographic features. Locations in the main stream at the center of the Countercurrent where the velocity of the current is around 2.0 knots or more are not good fishing grounds.

2. Transparency

If we make a comparison of the clarity of the waters of the Northern Equatorial Current and the Equatorial Counter-current, we find that the former has a higher transparency than the latter. In other words, the Northern Equatorial Current is clearer than the Counter-current. This is because the Counter-current contains a great proliferation of diatoms, which are a kind of plant plankton.

Transparencies of 25 to 35 meters are suitable, and transparencies below this range are the most unsuitable.

(Transparencies are measured by placing a white disk 30 cm in diameter in the water and finding the limit of its visibility. Of course the clearness or cloudiness of the weather, the hour of the observation, and the angle of the rope on which the disk is lowered must be fully taken into consideration.)

3. Water temperature

The temperature of the surface waters in the South Sea islands varies little throughout the year. It remains between 28 and 30 degrees. In the past it has been difficult to locate good fishing grounds by the water temperature, as is done in Japanese waters, and consequently little attention has generally been paid to this factor. However, investigations by the Fisheries Experiment Station of the South Seas Government-General and the results of a study of the poor fishing for yellowfin in Palau waters this year (January, February 1941) have shown that even within the Counter-current the water temperature at the 100-meter level sometimes drops to below 20° and that this is the greatest cause of poor fishing. Because of this the water temperature in the Counter-current has come to be regarded as an important oceanographic factor. In the Equatorial Counter-current the 100-meter level, which bears the closest relationship to the tuna longline fishery, usually shows temperatures of 24° or above. When a phenomenon like that which appeared this year arises, it also affects the temperatures in the surface waters, and when the surface temperature falls to 27° or lower the fishing becomes poor. The coastal waters around the principal islands of the South Seas sometimes show surface temperatures between 27° and 28° for a short time from January to March, and this is a phenomenon which is worthy of attention.

4. Water color

The best color is III on Forel's scale. The next best is a color between II and III, followed in order of suitability by II and the shades between III and IV. Color III and the colors between II and III predominate in the Counter-current, and IV is rarely seen. Water color is related to transparency in such a way that higher or lower water colors mean greater or lesser transparency.

(III) Good fishing grounds from the point of view of catch concentration

The following is an attempt to list the catch ratios for tuna grounds which are known at present. These are of course based only on the results of one or several attempts at experimental fishing, but while some of them represent the best records which have been made lately in the areas, most of them can be regarded with some confidence as comparatively accurate average figures.

Area of the Fishing Ground	Catch Ratio
east of Taiwan	2.0
northern part of South China Sea	4.2
southern part of South China Sea	4.8
off Luzon	5.8
off Hainan	4.6
off Cochin China	7.2
off Borneo and Sarawak	6.2
Sulu Sea	7.0
Celebes Sea	9.5
northern part of East Philippines Sea	7.8
southern part of " " "	11.1
Molucca Strait	7.4
Flores Sea	10.3
Banda Sea	5.0
off Java	6.1
off eastern Sumatra	8.4
northern Carolines	6.0
southern Carolines	8.0
northern Marshalls	uninvestigated

The catch ratio is the number of fish taken per 100 hooks. (See the accompanying figure.)

Equatorial Fishing Grounds	Catch Ratio	
sea area south of the Marshalls	18.1	(survey by Zuihō Maru in November 1940)
180 miles southeast of Ponape	17.2	"
300 miles southeast of Truk	23.7	"
east of Morotai	17.1	" March 1941
east of Halmahera	27.0	" "
north of New Guinea (south of Palau)	1.40	" May 1941
south of Palau (west of Tobi I.)	21.3	" March 1939
Banda Sea (south of Ceram)	20.5	" July 1941
eastern Banda Sea	16.0	" "
southern Banda Sea (west of Tanimbar)	14.0	" "

(IV) Records of Catches on Southern Fishing Grounds

Fishing Ground	Catch Records (Oct. 1939 - Jan. 1941)	
1. 600 miles south of Saipan	total catch	65,732 fish
	yellowfin	46,811
(Fishing Ground A)	big-eyed	7,057

	spearfish 9,102
38° -- 7° north latitude	others 2,762
142° -- 149° east longitude	value of all landings 1,395,263 ¥
2. south of Saipan	total catch 81,269 fish
	yellowfin 62,831
(Fishing Ground B)	big-eyed 7,632
	spearfish 8,075
3° N -- $1^\circ30'$ S	others 2,731
$142^\circ30'$ -- 147° E	value of all landings 1,908,672 ¥
3. south of Truk	total catch 67,114 fish
	yellowfin 50,336
(Fishing Ground D)	big-eyed 6,403
	spearfish 8,606
3° -- 7° north latitude	others 1,769
149° -- 115° east longitude	value of all landings 1,084,661 ¥
4. 350 miles south of Truk	total catch 47,036 fish
	yellowfin 34,799
(Fishing Ground C)	big-eyed 3,745
	spearfish 5,474
	others 3,018
	value of all landings 943,750 ¥
5. south of Ponape	total catch 13,197 fish
	yellowfin 9,383
(Fishing Ground E)	big-eyed 1,688
	spearfish 1,593
3° -- 7° N	others 533
149° -- 159° E	value of all landings 308,540 ¥
6. south of Palau	total catch 6,990 fish
	yellowfin 4,911
(Fishing Ground F)	big-eyed 1,165
	spearfish 634
3° -- 7° N	others 280
$134^\circ20'$ -- 133° E	value of all landings 150,235 ¥
7. 300 miles south of Palau	total catch 2,184 fish
	yellowfin 1,800
(Fishing Ground G)	big-eyed 214
	spearfish 20
$2^\circ40'$ -- $10^\circ30'$ N	others 150
$133^\circ30'$ -- 135° E	value of all landings 21,562 ¥

(V) Japanese Tuna Grounds and South Seas Tuna Grounds

From a comparison of the catches made by fishing boats operating in Japanese waters and those which fish in the South Seas the superiority of the South Seas grounds is readily apparent. This is of course a very general indication and does not accurately define the value of the fishing grounds.

Table Comparing Catches Made by Boats in the South Seas and Japanese Waters

Boats Fishing Japanese Waters

Value of Catch	Number of Boats	Notes
under 1,000 ¥	8	
1,000-2,000	11	
2,000-3,000	6	
3,000-4,000	10	
4,000-5,000	6	
5,000-6,000	4	
6,000-7,000	3	
7,000-8,000	13	
8,000-9,000	3	
9,000-10,000	3	
10,000-11,000	8	
11,000-12,000	2	
over 12,000	4	
total	81 boats	

(note) Classified by the average value of catch per voyage for each boat

Boats Fishing South Seas Grounds

Value of Catch	Number of Boats	Notes
under 5,000 ¥		
5,000-10,000	3	
10,000-15,000	6	
15,000-20,000	7	
20,000-25,000	12	
25,000-30,000	7	
30,000-35,000	7	
35,000-40,000	3	
40,000-45,000	3	
45,000-50,000	1	
50,000-55,000	1	
55,000-60,000	1	
over 60,000		
total	52 boats	

(Note) Classified according to the average value of catch per trip for each boat. [TN. These figures seem far too high in view of what is known about tuna catches and tuna prices in Japan before the war. It is suggested that they be regarded as unverified and possibly erroneous.]

(VI) Plankton of the Fishing Ground Areas and the Ecology of the Tuna

We present here as one type of data for the clarification of the relationship between oceanographic conditions and tuna fishing conditions

a partial report on studies of the ecology of tuna and plankton. This material is drawn from a report of biological research done by the Palau Tropical Biological Research Station for the South Seas Government-General Fisheries Experiment Station.

(A) Relationships between types and quantities of plankton and ocean currents

Studies of this type in tropical waters, particularly the Inner South Seas area and equatorial waters, have been very few. About the only ones which have been made are the quantitative studies of Motoda (1938) and Marukawa (1939) and the qualitative study by Haneda (1938).

1. The marine plankton of the South Seas region consists mostly of copepods, schizopods, chaetognaths, pteropods, mollusks, larval crabs, polychaetes, jellyfish, radiolarians, dinoflagellates, diatoms, and blue-green algae. In the Northern Equatorial Current the copepods are most conspicuous while the diatoms predominate in the Counter-current.

2. Larvae of bottom-dwelling animals which are the mature forms of coastal plankton are rarely found in pelagic waters. (Revealed by the inspection of plankton material)

3. The togenashi eboshimijinko [a daphniid] is taken only in the Northern Equatorial Current area.

4. Diatoms are poor both in quantity and number of species in the Northern Equatorial Current, but in the Counter-current area they are remarkably abundant in both respects, a fact which shows a conspicuous difference between the two areas.

5. The blue-green alga Lyngbga [?] is distributed throughout the whole area.

6. Seasonal variations in composition and quantity of the marine plankton of the South Seas area can be detected. The various larval forms appear more abundantly in the plankton in the autumn than in the spring. The quantity of plankton increases in the spring and autumn.

(B) Stomach contents of the yellowfin tuna

A study extending over one year was made of the stomach contents, but most of the material recovered was so far digested that it could not be identified below the genus.

It is difficult to distinguish any difference between the sexes with regard to the total quantity of the stomach contents. Judging from the time at which the fish were taken and the progress of digestion it appears that the fish feed at night. If we classify the stomach contents we find that they all consist solely of pelagic planktonic animals. It is especially surprising that in many cases large numbers of fish such as a species of trunk-fish and hard-shelled mollusks like the paper-nautilus are found. In

other cases juvenile carangids [akamuro], mackerel, and sphyraenids, as well as mature skipjack (38.3 -- 40.5 cm in length) are discovered in the stomachs.

(C) Age determinations on tuna (by the vertebrae)

Age determinations have been made using the first to the sixth cervical vertebrae from yellowfin tuna living in equatorial waters, but the method is extremely inaccurate and various values are obtained depending on the observer. Ages of seven to eight years are determined, but judging by the length of the fish and the state of development of their gonads these values are thought to be somewhat unreasonable.

Dr. Masamitsu Ōshima has proposed that in the future a study be made of the scales from the anterior part of the belly.

(D) Gonads of the tuna

In general the stage of ripeness of the reproductive organs in both male and female yellowfin tuna is about the same throughout the year, and at all times of the year the schools which are fished are found to contain a mixture of fish in markedly high and low stages of development. From a superficial examination it appears that from January to May the schools are riper than they are around September.

(VII) Conclusion

Boats which operate in the southern tuna grounds should fully utilize the results of scientific studies of the South Seas tuna fishery in order to proceed to the opening up of new fishing grounds. The number of persons in Japan who advocate the development of the South Seas fisheries and the number of technicians who have something to say on the subject of investigations of the southern tuna fishery has greatly increased of late. One cannot, however, help being amazed at the paucity of factual knowledge about the scientific study of the tuna fishing grounds of the South Seas.

It is regrettable but unavoidable that in the foregoing discussion of "oceanographic factors of good fishing grounds" it has been impossible fully to explain the matter so that it might be easily understood by persons operating boats in southern waters.

To summarize, those who pursue the yellowfin tuna on the equatorial fishing grounds should first of all find the Equatorial Counter-current and then seek the portions of its current area having a particular form. Within these areas they should look for waters where the velocity of the current is 0.5 to 1.5 knots, the transparency is 25 to 35 meters, and the water temperature at the 100-meter level is over 20°. The determination of the temperature at this level is difficult for the average fishing craft, but because the surface water temperature will also vary by about 1°, suitable waters can be found if the surface temperature is accurately measured, and consequently this is a point which requires careful attention. If the vessel proceeds into the southern latitudes, some variations will be found in these oceanographic factors. For example, this is true of the

southern part of the Banda Sea (east of New Guinea). If, however, the oceanographic factors described above can serve as reference data for directing the investigation of southern fishing grounds, the author will be happy. (August 21, 1941)

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Oceanographic Charts	Fisheries Experiment Station	published monthly
South Sea Fisheries	South Sea Fisheries Association	"
South Sea Islands	South Sea Islands Cultural Association	"

Industrial South Seas South Sea Islands Fisheries Association published monthly

Southward Progress Southern Industrial Investigation Society published monthly

Marine Fisheries Marine Fisheries Association published monthly

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[TN. A graph of catch distribution by latitude and longitude has been omitted because the figure was too illegible to be copied accurately.]

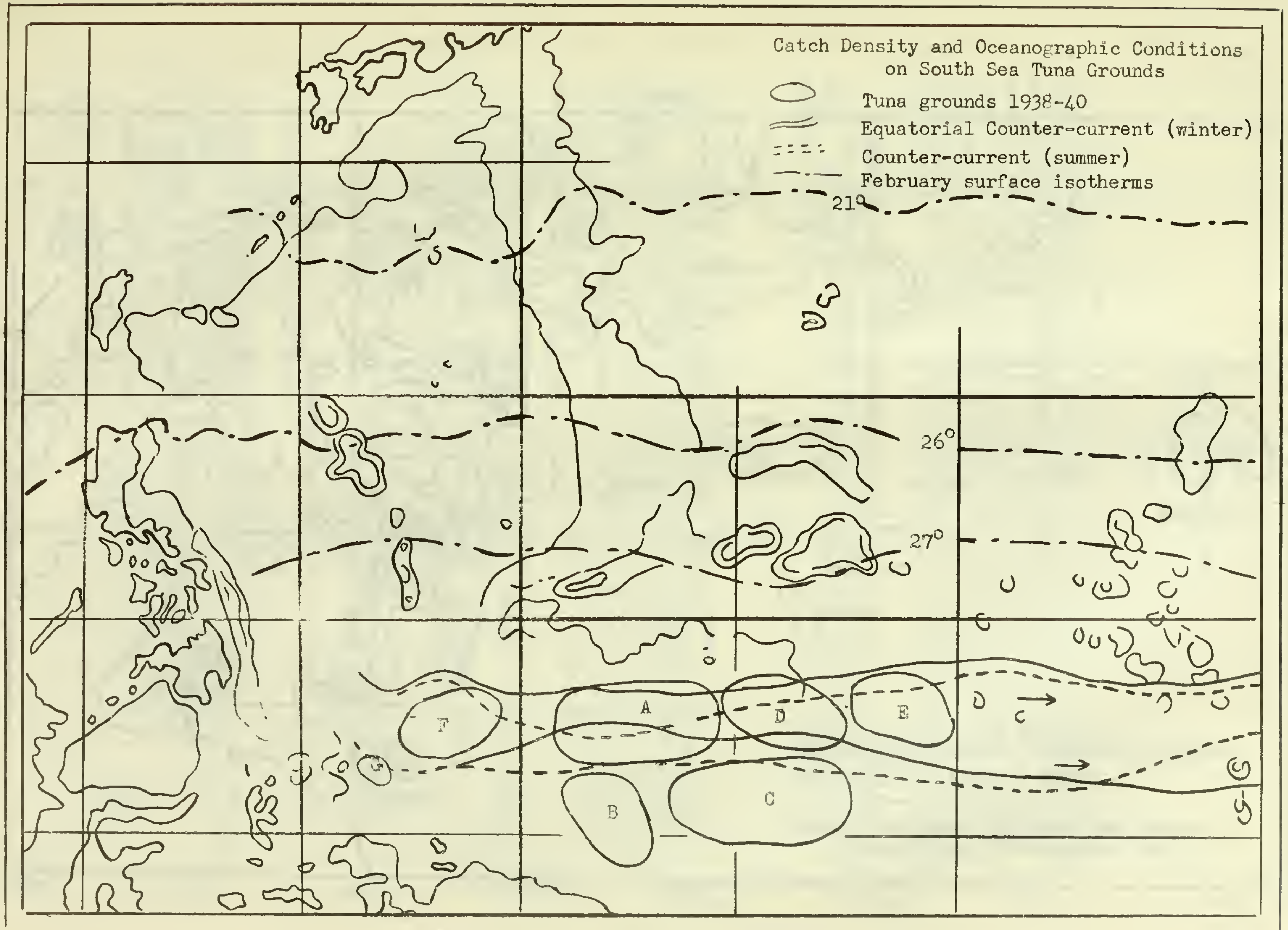

Catch Density and Oceanographic Conditions on South Sea Tuna Grounds
Tuna grounds 1938-40
Equatorial Counter-current (winter)
Counter-current (summer)
February surface isotherms
21°
26°
27°
A
B
C
D
E
F
G

Figure 1

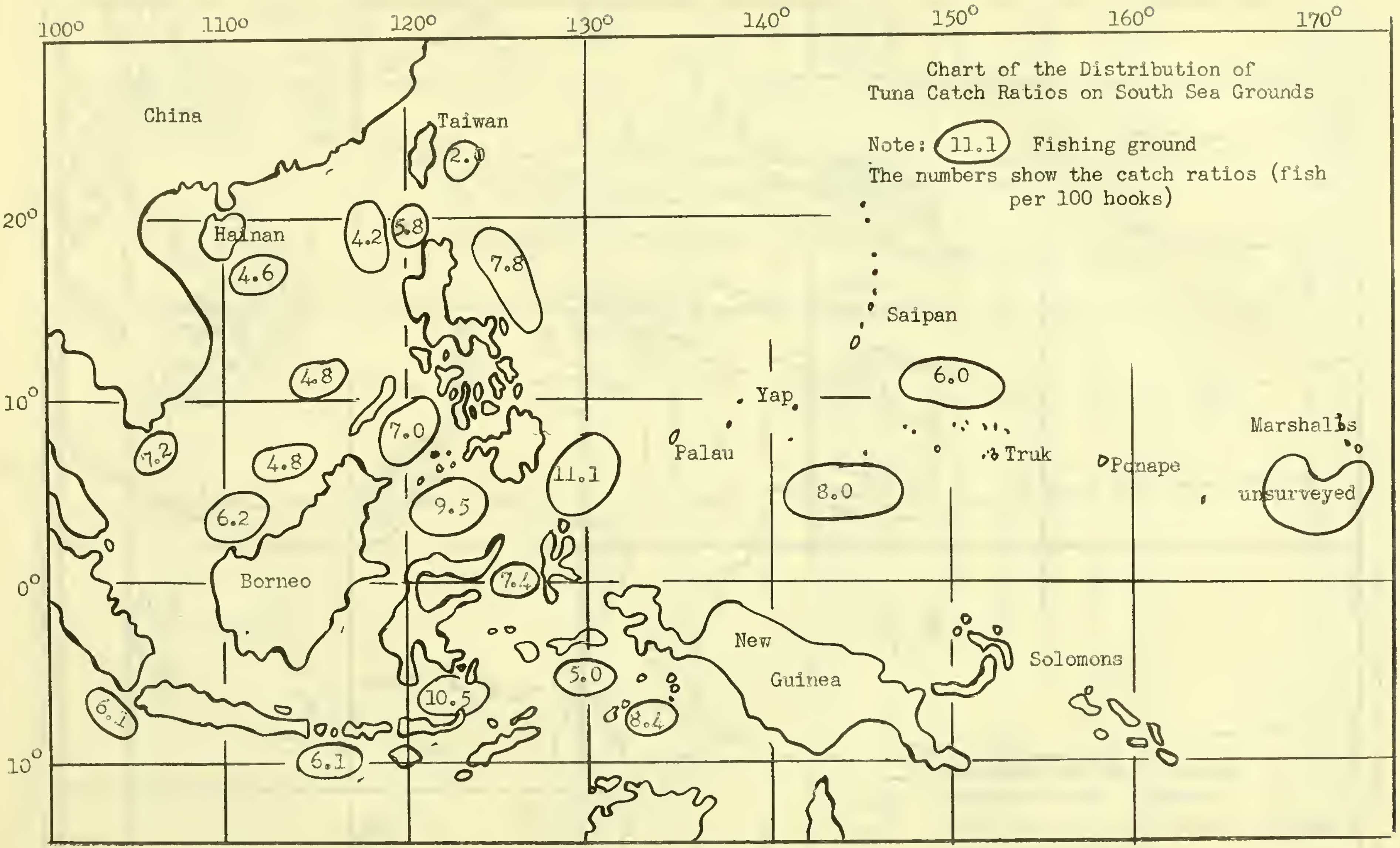

100°
110°
120°
130°
140°
150°
160°
170°
20°
10°
0°
10°
Chart of the Distribution of
Tuna Catch Ratios on South Sea Grounds
Note: 11.1 Fishing ground
The numbers show the catch ratios (fish per 100 hooks)
China
Taiwan
Hainan
Saipan
Yap
Palau
Truk
Ponape
Marshalls
unsurveyed
Borneo
New Guinea
Solomons
2.0
5.8
4.2
7.8
4.6
4.8
7.0
7.2
4.8
11.1
9.5
6.2
6.0
8.0
7.4
5.0
10.5
8.4
6.1
6.1

Figure 2

Tunas and Spearfishes

Preface

The study of the habits of marine fishes is for various reasons extraordinarily difficult, and particularly in the case of species like the tunas and the spearfishes, which migrate widely in the open seas, we may safely say that this is the most difficult of studies. Consequently what we know of the subject is extremely little, and furthermore, even in what we think we understand of it, it may be thought that there will probably be many points which will require correction as research progresses. That is how poor our knowledge concerning these fishes is.

What I have treated in this article is principally the distribution of these fishes in Japanese waters and in the seas of Greater East Asia. The data are chiefly based on results obtained by fisheries research vessels.

I. Species

Jordan and Evermann recorded one family, 5 genera, and 21 species for the tunas, and 2 families, 4 genera, and 32 species for the spearfishes. This is the total number of species existing on the earth, but actually it is very doubtful whether there are this many species, and among them some are cited which are clearly the same species under different names. Among these fishes the following are distributed in Japanese waters. First of all, for the tunas Dr. Kishinouye has reported the following 5 species:

1. *Thunnus orientalis* (Temminck & Schlegel) *maguro* [black tuna]
2. *T. germo* (Lacepede) *binnaga* [albacore]
3. *Parathunnus mebachi* (Kishinouye) *mebachi* [big-eyed tuna]
4. *Neothunnus macropterus* (Schlegel) *kihada* [yellowfin]
5. *N. rarus* (Kishinouye) *koshinaga*

The above species are generally distributed in Formosan waters and occur widely throughout the seas of Greater East Asia.

For the spearfishes the author has reported the following species as occurring in Formosan waters:

1. *Tetrapturus angustirostris* Tanaka *fūraikajiki* [short-nosed marlin]
2. *Istiophorus orientalis* (Temminck & Schlegel) *bashōkajiki* [sailfish]
3. *Makaira mitsukurii* (Jordan & Snyder) *makajiki* [true marlin]
4. *M. mazara* (Jordan & Snyder) *kurokajiki* [black marlin]
5. *M. marlina* Jordan & Evermann *shirokajiki* [white marlin]
6. *Xiphias gladius* Linne *mekajiki* [broadbill]

These are generally distributed throughout the seas of Japan and Greater East Asia.

II. Fisheries

The fisheries are carried on by skilfully utilizing the habits of these fishes. In offshore waters the fishing is chiefly done with longlines, but drift-net fishing is also carried on at times.

In longline fishing, as shown in Figure 4, the gear is linked together and suspended from the surface of the water. Fishing grounds are in the waters adjacent to Japan proper, in Formosan waters, and in the South Seas Government-General, of course, but the East Philippines Sea, the South China Sea, the Sulu Sea, and the Celebes Sea also have already become operating areas. Aside from these waters the extensive warm seas of the Pacific and Indian Oceans are expected to afford fishing grounds, and some investigations are already being made in those areas. In the area between 20° north latitude and 15° south latitude and 90° and 180° east longitude the extent of the fishing grounds already surveyed actually amounts to three and one-half million square miles. Furthermore, it is extremely gratifying that these surveys have all been made by our country. As far as the tuna longline fishery is concerned, the seas of Greater East Asia were already our fishing grounds even before the Great East Asia War.

When, as will be described below, the tuna move northward in the spring and summer through the waters adjacent to Japan proper, they come in extremely close to shore and then a fishery with stationary gear is carried on with the large set-nets which are placed everywhere along the coasts.

The spearfishes have in general the habit of swimming close to the surface with a portion of their dorsal and caudal fins protruding from the water under conditions where the current and the wind are running in opposite directions and the surface of the sea shows whitecaps. Because of this, in addition to the above-mentioned fishery, a special harpoon fishery is carried on. In this fishery the gear used is a harpoon. When a fish is sighted swimming at the surface, the boat gives chase to it and, arriving at close range, the fish is captured by throwing the harpoon at it in this extremely thrilling fishery.

In addition to the above a trolling fishery, in which an artificial bait is pulled astern of the boat, and a pole and line fishery, like that for skipjack, are carried on, but they are on a small scale.

This is not related to the fishery, but it is interesting to see how the various species act differently when they are caught on the hooks of a longline. The catch of the longline fishery is largely tunas, spearfishes, and sharks. When tuna are hooked they have the habit of making one very deep dive. In the case of a large black tuna the fish will drag two or three glass ball floats of about 30 cm diameter down into the water. In extreme cases they dive so deep that glass floats with a thickness of 1 cm are occasionally broken by the water pressure.

The spearfishes, on the other hand, leap several times on the surface and then run about horizontally, causing trouble by entangling the

neighboring branch lines. The sharks are extremely sluggish and swim about quite calmly and quietly. (Figure 1)

III. Distribution and Migration

A. Horizontal distribution

When it comes to distribution, direct observation is impossible so it must be deduced from the catch of the fisheries.

a. Outline of the distribution in Japanese waters

These fishes are pelagic in nature and although they may when young live along the coasts to some extent, in general their growth and reproduction take place in offshore waters. Since they are essentially fishes of the tropical and subtropical seas, they occur throughout the year in the waters of the low latitudes, but they appear only seasonally in the seas of the high latitudes.

Through the spring and summer, as the water temperatures of the Kuroshio gradually rise, these fish move northward along the current. First come the black tuna, then the spearfishes appear with the albacore showing up in the offshore waters at about the same time, and then the yellowfin and the big-eyed tuna follow.

The speed of migration is rather fast, for example, a black tuna which is off southern Kyūshū in February or March will already have reached the waters off Sanriku or Hokkaidō in the latter part of June.

In Formosan waters all species except the black tuna are present to some extent the year round. In the Pacific coastal waters, or in other words, in the current area of the Kuroshio, when the northeast monsoon begins to blow in October the migration of the spearfishes begins and the harpoon fishery continues until April of the following year. The fishing grounds are for the most part within 30 miles of the coast. The schools move gradually from south to north, but the speed of this movement is extremely slow and at the end of the fishing season the schools have reached the vicinity of Hōkasho. Throughout the fishing season white marlin [*M. marlina*] are most abundant, while the number of true marlin [*M. mitsukurii*] increases in the middle of the season and the number of black marlin [*M. mazara*] increases towards the end of the season. Around December the short-nosed marlin [*Tetrapturus angustirostris*] occurs abundantly in offshore waters centered 150 miles from the coast. The sailfish [*Istiophorus orientalis*] occurs densely for a few months centered around June. Yellowfin are comparatively few, big-eyed tuna are rather abundant, and *koshinaga* [*N. rarus*] are most numerous during the season of the northeast monsoon. Black tuna [*T. orientalis*] appear from April to June, as set forth below.

The northeast monsoon season is also the fishing season in the South China Sea area. In the early part of the season generally fishing is most active in the southeastern part, that is, in the area adjoining the

Sulu Sea, but it gradually extends over the whole area and fishing becomes good from the vicinity of Dangerous Ground to the Annam area.

The greater part of the catch is yellowfin, making up 90 per cent of the tuna and spearfish taken. There are few big-eyed tuna, and albacore appear only in the northeastern part of this area. All of the species of spearfish are found, but M. marlina, M. mazara, and M. mitsukurii are most abundant.

From the middle of March to May active migration of spearfishes is seen from the waters off Annam to the Hainan I. area. The main species is M. marlina. The sailfish is most abundant in the summer, just as it is on the Pacific side.

From the middle of March to the first part of June the black tuna appear in the northeastern part of this area and the fishery for them becomes active at the same time that it does in the Pacific northeast of Luzon.

The area under the South Seas Government-General will be discussed later.

In what follows I will attempt a brief outline of the distribution of a number of the important species.

(a) maguro [black tuna, T. orientalis]

According to Dr. Kishinouye, the southern limit of the distribution of this species is around 32°N and it does not occur in the Ryūkyūs, Ogasawaras, and Taiwan. Its northern limit is given as approximately 46°N, and its range of distribution with regard to water temperature is 5° - 20°C, with 15°C the optimum. It likes lower temperatures than any other species of tuna. Fish which are in the vicinity of 32°N begin their gradual northward movement in the spring, a part of them going through the Tsushima Strait into the Sea of Japan while the majority migrate along the Pacific coast. In the course of this migration the fish come in very close to the coast. In the autumn they move south again, but their course is thought probably to lie through the offshore waters.

It was in 1935 that it became clear that this species also occurs in Formosan waters, and in that year 50,000 yen worth of these fish were landed. Thereafter the catch increased from year to year, and in recent years it has amounted to more than one million yen. Ordinarily the first catches are made in the middle of March, and the peak is reached in April and May. In the early part of June many of the fish are seen leaping on the surface, and thereafter they suddenly disappear. In normal years the first catch is made in the vicinity of the 100-fathom line in the northern part of the South China Sea, the fishing grounds rapidly extend over all of the northern part of the South China Sea, through the Bashi Strait, and into the Pacific northeast of Luzon, and at the end of the season fish are taken even in the vicinity of Yonakuni I. These fish appear suddenly and disappear suddenly, and at present their migratory routes are completely unknown.

Generally the fish are extremely large and those taken early in the season are commonly over 300 kg, but with the passage of time the fish gradually become smaller and those taken in the latter part of the season are mostly around 150 to 200 kg. These are markedly larger than those taken along the coast of Japan proper, where they would be considered on the large side.

Considering the size of the fish, the season of their migration, and the state of maturity of their gonads, it is probably correct to regard the black tuna which come into Formosan waters as separate from the schools which move northward off the coasts of Japan proper. In recent years we have data from which it is inferred that this species also occurs in the Indian Ocean area. They are also taken occasionally in Hawaiian waters. If we take into consideration all of these facts, probably the belief held hitherto that this species occurs only in fairly northerly regions needs to be corrected.

(b) binnaga [albacore, T. germo]

The pelagic character of this species is extremely marked, and the fish do not come in close to the coast very much. Ordinarily they are taken with longlines especially designed to fish for this species, but they are also taken sometimes on longlines used for yellowfin, and the catch from the areas under the South Seas Government-General contains a mixture of about 1 per cent of this species. At Takao in Formosa, too, the landings of this species amount to 10,000 yen or more per year, the fishing grounds being almost entirely limited to the northeastern part of the South China Sea and particularly the southern part of the Taiwan Strait. The fishing season is during the northeast monsoon.

Except for this area there is no record of its capture in the rest of the South China Sea, the Sulu Sea, the Celebes Sea, or the sea areas connected with the Banda and Flores seas.

Since the fishing gear is not especially designed to catch this species, but rather to fish for yellowfin, we cannot decide unqualifiedly that the albacore does not occur because of the above-mentioned lack of records of its capture, however, in the South Seas Government-General and in the northern part of the South China Sea a certain number of these fish are taken on the same kind of gear. Therefore we can assume that in these areas where there are absolutely no records of its capture, the distribution of this species is either extremely sparse or else it does not occur at all. In other words, such enclosed seas are not suitable habitats for this species. Before the war this remarkably pelagic species was taken abundantly in the Midway area.

(c) mebachi [big-eyed tuna, P. mebachi]

Quantitatively this species is not as abundant as the yellowfin, but it is widely distributed throughout the warm seas. The northern limit of its distribution is said probably to be about 36°N and its range of water temperatures is taken to be 13° - 25°C. It is notably pelagic

in nature and has not yet been taken in the Sea of Japan, furthermore, as will be detailed below, even in the south it is scarce in enclosed sea areas, while it is abundant in the area of the South Seas Government-General.

(d) kihada [yellowfin, N. macropterus]

This is the most common species in warm seas and is extremely widely distributed. The northern limit of its range is about the same as for the big-eyed tuna, but in late summer it is occasionally taken as far north as the neighborhood of 40°N. It occurs in waters of 15° - 25°C, and the optimum temperature is said to be 20°C, however, in the South the yellowfin appears generally to occur in waters of higher temperatures.

In recent years the fishing grounds in the South Seas Government-General have become famous and many boats have gone to fish there. As a result it has become known that in general yellowfin are scarce in the Equatorial Current and abundant in the Equatorial Countercurrent.

(e) spearfishes

Because the species are difficult to distinguish, the distribution by species has not yet been made very clear. Considered very summarily, it appears that whereas the yellowfin is most abundant in the Equatorial Countercurrent, the spearfishes are most abundant in the Equatorial Current and in the Kuroshio.

b. Outline of the distribution in the various areas of the Southwest Pacific

In the sea areas of the South the year is divided into two seasons of northeast winds and southwest winds. The former prevail from about October to March of the following year, while the latter last from April to September. With this seasonal change the ocean currents also change, and the distribution of fishes also necessarily changes.

Table 1 is made up of the combined results of past experimental surveys. In the table "number of hooks used" is the total number of hooks fished in past surveys added together without regard to year or season. The "catch rate" shows the number of fish taken per 100 hooks fished. It represents only tunas and spearfishes and does not include sharks or other miscellaneous fishes. The "rate of appearance" is the proportion of each kind of fish in the total catch of tunas and spearfishes, or in other words, the composition of the catch. Table 2 shows the catch with regard to seasons.

Table 1 Fish Catch Situation in the Southwest Pacific

Area	Number of Hooks used	Catch Rate (%)	Ratio of Appearance in Catch			Weight of Yellowfin (kg)
			Yellowfin (%)	Big-eyed (%)	Spearfishes (%)	
east of Formosa	7,932	2.81	39.1	14.4	36.7	47.2
E. Philippines Sea	10,234	6.35	56.4	2.3	41.3	33.0
South Seas Govt-Genl.	220,626	5.23	79.2	9.3	11.5	33.0
South China Sea	110,560	4.65	90.3	4.5	5.2	unknown
Sulu Sea	4,600	3.96	unknown	unknown	11.1	47.1
Celebes Sea	157,156	4.37	unknown	unknown	16.3	44.0(Celebes) 36.0(eastern)
Papua, Solomons } coasts	21,792	4.21	71.8	7.1	21.1	37.0
Banda, Flores } seas	81,779	8.40	89.5	3.3	7.2	48.5

Table 2 Fish Catch by Seasons in the Southwest Pacific

Area	Southwest Monsoon		Northeast Monsoon	
	Number of Hooks	Catch Rate	Number of Hooks	Catch Rate
East of Formosa	900	1.78	7,032	2.94
East of Philippines	7,840	7.98	2,394	0.67
South Seas Govt.-Genl.	115,099	5.40	105,527	4.18
South China Sea	4,158	3.32	106,402	4.69
Sulu Sea	none	none	4,600	3.96
Celebes Sea	10,493	8.86	146,663	4.06
Papua, Solomons } coasts	10,500	4.39	11,292	4.04
Banda, Flores } seas	80,089	8.56	1,690	7.34

As the foregoing table shows, the fishing is generally better during the southwest monsoon. This is considered to indicate a more dense distribution of the fish. Only in the South China Sea and the waters east of Formosa is the fishing better during the northwest monsoon, but due to the paucity of data it is not clear whether or not this tendency is decisive.

According to Table 1 the highest catch rates were obtained in the Banda and Flores seas, and in these areas the seasonal changes were not very pronounced.

To go a bit more into detail, the outlines of the distribution by sea areas are as follows. The seas east of Formosa and the South China Sea are omitted from consideration here as they have already been generally described.

(a) East Philippines Sea (3° - 20°N, 123° - 131°E)

This area is divided into three sections by the pattern of the currents. The northern section is the area of origin of the Kuroshio, where the Equatorial Current begins to turn northward, and may be generally considered to lie north of 15°N. The central section is the area where the Equatorial Current impinges upon the Philippine Archipelago, and can be considered to lie roughly between 10° - 15°N. The southern section is in the Equatorial Countercurrent area and may be considered to lie south of 10°N. The catch in these three areas is as shown in Table 3.

Table 3 Catch by Regions (East Philippines Sea)

Section	Yellowfin		Black Marlin	
	Number of Fish	Catch Rate	Number of Fish	Catch Rate
northern	19	1.7	57	4.9
central	50	3.5	57	3.7
southern	289	9.8	50	1.7

Note. The catch rate is the ratio per 100 hooks.

Table 3 shows the results of the survey made by the Shōnan Maru (fisheries research vessel of the Formosa Government-General) from June to September of 1937, in which the catch was almost exclusively composed of yellowfin and black marlin. Table 3 shows clearly the following facts:

i. At this season black marlin predominate overwhelmingly in the northern section.
ii. In the central section yellowfin and black marlin are about equal in abundance.
iii. In the southern section yellowfin are overwhelmingly predominant.
iv. Black tuna are most numerous in the source of the Kuroshio and in the Equatorial Current, while yellowfin are more abundant in the Equatorial Countercurrent.

Big-eyed tuna are also taken to some extent. They are scarce in the northern section and increase in abundance in the south, showing the same tendency as the yellowfin.

The results of a survey of the central section of this area by the Takao Maru (research vessel of Takao Province) in September, 1940, exhibit marked differences from those obtained by the Shōnan Maru. The area surveyed was the central section and seasonally the Takao Maru's survey was about two months later. The fishing gear of the two vessels differed in its construction, that of the Takao Maru being designed to fish at shallow levels, however, the remarkable differences shown in Table 4 cannot be thought to be due solely to the construction of the gear and must necessarily be regarded as seasonal differences. This means that in this area the movements of the schools are rather marked, and it is thought that around September there is a rather dense concentration of short-nosed marlin.

(b) South Seas Government-General (0° - 10°N, 130° - 180°E)

The very remarkable thing about this area, as can be seen clearly from Table 1, is the abundance of big-eyed tuna [sic]. Throughout the whole of the year the fishing is somewhat better than in the South China

Table 4 Comparison of Catch Composition (East Philippines Sea)

Vessel	Catch Rate	Yellowfin		Big-eyed		Black Marlin		True Marlin		Sailfish		Short-nosed Marlin	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Shonan M.	7.2	54	47.6	3	2.4	57	50.0	0	0	0	0	0	0
Takao M.	2.3	24	48.0	0	0	12	24.0	2	4.0	4	8.0	8	16.0

Sea, the Sulu Sea, the Celebes Sea, and, across the Equator, the coastal waters of Papua and the Solomons. From the results of past surveys it appears that the schools are most densely concentrated generally around May and November, that is, just after the change in the seasonal winds. The seasonal changes are, however, slight, and fish are taken the year round with no great variation.

The area within which fishing is carried on at present lies for the most part between 0° and 10°N. If we compare, without regard to the longitude, the catches made north and south of the line of 5° north latitude, they are as shown in the following table. This table, however, does not show the data from a single year, but is a summary of the results of surveys made in several recent years.

Table 5 Comparison of Catch Rates North and South of 5°N
(Within South Seas Government-General)

Area	Number of Hooks	Catch Rate (%)
north of 5°N	85,410	1.70
0° - 5°N	145,610	6.05

Note. The catch rate is the number of fish taken per 100 hooks.

Table 5 shows clearly that the schools are denser in the waters of the lower latitudes than they are in the higher latitudes. It is said that in general yellowfin are abundant in the Equatorial Countercurrent, but it can be seen that they are particularly numerous south of 5°N.

The yellowfin of this area are generally small, averaging about 33 kg, about the same size as the yellowfin of the East Philippines Sea. All species of spearfishes occur in this area, but the black marlin and the sailfish seem to be especially abundant.

(c) Sulu Sea

There is very little data on this area, but judging by the activities of fishing boats the schools are most concentrated in the early part of the northeast monsoon, and besides yellowfin many broadbills and black marlin are taken.

(d) Celebes Sea

Spearfishes are abundant in this area. Table 1 includes both the Celebes Sea west of 125°E and the eastern sea area around 130°E. The schools are clearly different in these two sea areas, yellowfin being somewhat fewer and the occurrence of spearfishes more conspicuous in the eastern area than in the Celebes Sea.

As is clear from Table 2, seasonal changes are extremely marked in this area. Fishing is extraordinarily active during the southwest monsoon, presenting its greatest activity from July to September. This tendency is approximately the same in the contiguous East Philippines Sea and, to a lesser extent, in the South Seas Government-General and to the south in the Banda and Flores seas. The cause is not clear, but it is thought to be intimately related to the ocean currents.

(e) Coastal Waters of Papua and the Solomons (0^{o} - 15^{o}S, 130^{o} - 170^{o}E)

Compared to the areas under the South Seas Government-General in a corresponding position on the other side of the Equator, the fishing is somewhat inferior. By comparison, in this area spearfishes are extraordinarily numerous, and big-eyed tuna are slightly fewer. In general the spearfishes seem to be most abundant near islands and in straits. The yellowfin are somewhat larger than those taken in the South Seas Government-General, and the seasonal changes in the fishing situation, just as in the South Seas Government-General, are not too pronounced.

(f) Banda and Flores Seas

Yellowfin occur densely in this area, while big-eyed tuna and spearfishes appear to be comparatively scarce. The yellowfin are generally large, and there seems to be no great variation in the density of distribution throughout the year. We have not yet been able to obtain any data on it, but it is thought that this area has an important significance as a spawning ground of the yellowfin.

The size of the yellowfin, the catch rate, and the composition of the catch resemble the Indian Ocean coast of the Lesser Sundas more than they do the contiguous sea areas to the north. (See tables 1 and 6.) This fact can be considered as indicating that the schools of this area bear a deep relationship to the Indian Ocean area, and this, considered from the point of view of the set of the currents, is very natural (see Figure 2).

If we summarize the above-described distributional situation for the tunas and spearfishes in the Southwest Pacific and its connected sea areas,

1. Yellowfin, big-eyed tuna, and spearfishes are distributed throughout all areas of the Southwest Pacific all the year round.

2. The most common species is the yellowfin.

3. As far as we have been able to ascertain at present, the tuna (black tuna) occurs only north of the coastal waters of northern Luzon.

4. Big-eyed tuna are in general more numerous in pelagic waters in the low latitudes and are fewer in enclosed sea areas.

5. The albacore is even more markedly pelagic in nature, and hardly occurs at all in enclosed sea areas.

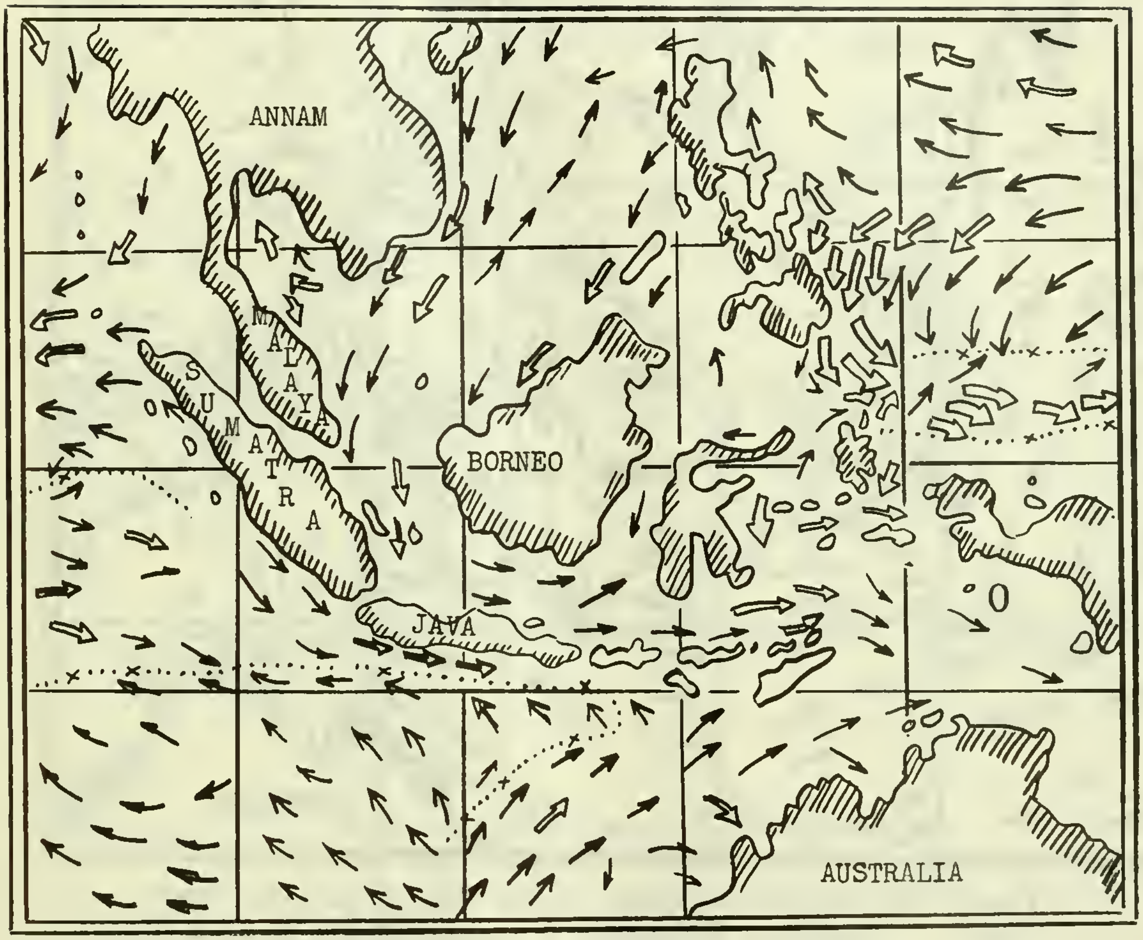


Figure 2a Surface Currents in the Seas of Greater East Asia
February - March (According to Kōji Hidaka in Vol.2, No.7 of this journal)

over 24 miles per day

12 to 24 miles per day

less than 12 miles per day

current boundary

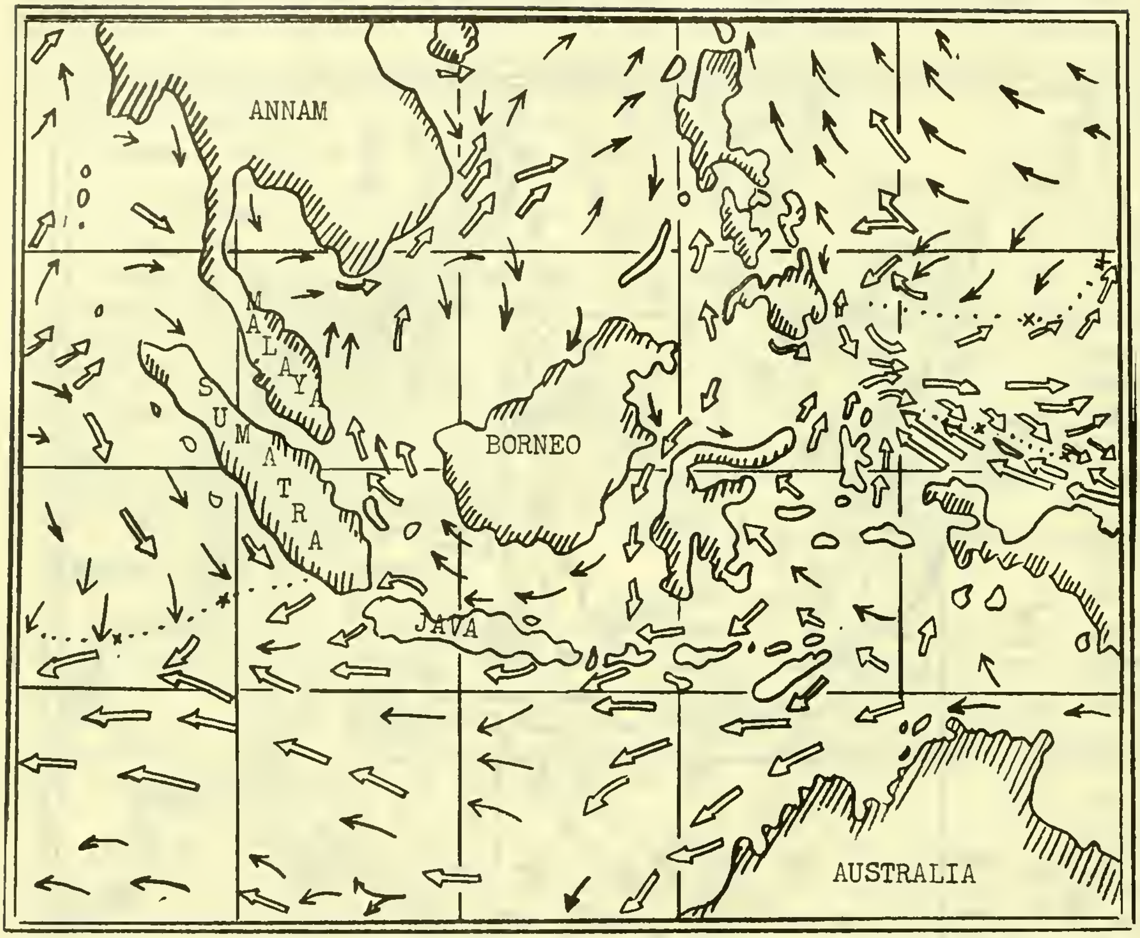


Figure 2a Surface Currents in the Seas of Greater East Asia August - September (According to Kōji Hidaka in Vol.2, No.7 of this journal)

over 24 miles per day

12 to 24 miles per day

less than 12 miles per day

current boundary

Table 6 Fish Catch Situation in the Indian Ocean Region

Area	Number of Hooks Used	Catch Rate (%)	Ratio of Appearance in Catch			Weight of Yellowfin
			Yellowfin (%)	Big-eyed (%)	Spearfishes (%)	
Lesser Sundas	48,756	9.19	88.6	3.8	7.6	48.0
Java coast	20,628	3.89	67.8	17.4	14.8	49.6
Sumatra coast	147,428	10.64	85.9	8.2	7.1	33-35* 48.9**
Andaman Nicobar coasts	15,568	6.23	89.2	4.2	6.0	40.0

Note: *north of the Equator **south of the Equator

6. The spearfishes appear generally to be most abundant in the vicinity of islands.

7. With regard to the yellowfin

i. They are generally more numerous during the southwest monsoon.
ii. In the low latitudes they are generally not subject to much seasonal variation.
iii. In offshore waters of the low latitudes the fish are generally small.
iv. In the higher latitudes and in enclosed sea areas the fish are generally large.
v. In the Celebes Sea some degree of peculiarity can be seen in that, although it lies in the low latitudes, there are marked seasonal variations.

8. From a consideration of the catch rates, the composition of the catch, and the size of the yellowfin, it appears that there are several populations in the Southwest Pacific, but nothing has as yet been ascertained concerning their relationships.

c. Outline of the Distribution in the Indian Ocean

The areas which have been surveyed in the Indian Ocean region are the coastal waters of the Greater and Lesser Sundas and of the Andaman and Nicobar Islands. If these data are presented according to the outline used in tables 1 and 2, they are as shown in tables 6 and 7.

Table 7 Catch by Seasons (Indian Ocean)

Area	Southwest Monsoon		Northeast Monsoon	
	Number of Hooks	Catch Rate	Number of Hooks	Catch Rate
Lesser Sundas	2,215	6.23	46,546	9.33
Java	none	none	20,628	3.87
Sumatra	300	3.67	147,128	10.72
Andaman Nicobar	none	none	15,568	6.23

(a) Coastal waters of the Lesser Sundas (8° - 13°S, 115° - 130°E)

As Table 6 shows, the catch rates are extremely high, indicating a great density of occurrence. The rates of appearance of big-eyed tuna and spearfishes are low, the yellowfin are large fish, and the numerical values closely resemble those of the Banda Sea and Flores Sea areas. (See

Table 1.) The data are few, but it appears that seasonally the fishing is somewhat better during the northeast monsoon. Fishing becomes most active around November, the time when the seasonal winds change and the movements of the schools seem to be at their height, but we have as yet no detailed knowledge concerning this point.

(b) Coastal waters of Java (6° - 10°S, 105° - 115°E)

The catch rates and catch composition in this area are entirely different from those of the contiguous sea areas to the east and west. During the northeast monsoon current boundaries appear in the vicinity of the Sunda Strait to the west and the Lombok Channel to the east, and the coastal waters of Java have water masses that are altogether different from those of the contiguous seas (Figure 2). To the east (coastal waters of the Lesser Sundas) and west (coastal waters of Sumatra) of these current boundaries extremely dense schools of fish are distributed. The coastal waters of Java show the peculiarity of water temperatures markedly lower than those of the adjoining areas, and it is thought that the occurrence of schools in this low temperature zone is sparse. Although there is a certain amount of fishing in this area, it is limited to the vicinity of eastern and western fringes, and in the central section almost no fish are taken.

The situation during the southwest monsoon is not known, but since the currents belong to the same system as those of the coastal waters of the Lesser Sundas it is presumed that the occurrence of the fish is probably fairly dense.

(c) Coastal waters of Sumatra (6°N - 6°S, 90° - 105°E)

The catch rates are amazingly high. Big-eyed tuna occur abundantly throughout the low latitudes, and are rather abundant everywhere in the area, though not as much so as in the South Seas Government-General. The spearfishes do not appear to be too numerous. In general a tendency can be perceived for the big-eyed tuna to be most abundant around December, gradually decreasing thereafter as the spearfishes become more numerous, the latter reaching their peak of abundance around February. (See Table 9.)

The northern and southern areas are clearly divided by a current boundary in the neighborhood of the Equator (see the dotted line on Figure 2) with the results shown in the following table.

Table 8 Fishing Situation by Areas
(Coastal waters of Sumatra, Hakuyo Maru, 1930)

Area	Number of Hooks	Catch Rate	Weight of Yellowfin (kg)
0° - 6°N	2,616	5.20	33 - 37
0° - 6°S	1,500	1.47	48 - 50

There is a marked difference both in the catch rates and in the size of the yellowfin.

Table 9 Fishing Situation by Sections (Sumatra Coast, Haruna Maru, 1932, 1933, 1934; Hakuyō Maru, 1933)

Month and Year	Vessel	Section	Catch Rate	Ratio of Appearance		Weight of Yellowfin (kg)
				Big-eyed	Spearfishes	
(i)1-33	Hakuyō	north of the Equator	17.31	3.5	4.1	35
(ii)11,12-32	Haruna	same	6.41	12.4	7.4	34.2
(iii)12-32,1-33	"	same	12.71	10.0	4.3	33.5
(iv)1,2-33	"	north of 3°N	10.95	6.3	11.9	33.4
(v)12-33,1-34	"	near Sunda Strait	9.23	12.5	7.5	49.8
(vi)1,2-34	"	0° - 6°N	10.40	5.3	8.8	43.2

In Table 9 the line (v) shows data for the vicinity of Sunda Strait. The catch rate is not greatly different from that obtained north of the Equator, but the size of the yellowfin is markedly different. In (vi) the reason for the large size of the yellowfin taken was probably that the fishing grounds had shifted far to the north of their normal positions.

The foregoing is an extremely summary presentation, but it seems to show clearly the differences between the schools north and south of the Equator. Seasonal changes are not known because of the lack of data.

(c) Coastal waters of the Andaman and Nicobar archipelagoes (6° - 14°N, 90° - 95°E)

Fishing is fairly brisk though inferior to that found in the coastal waters of Sumatra. The vicinity of 9°N seems to be a boundary on either side of which the fishing situation changes markedly and the size characteristics of the fish are different.

Table 10 Fishing Situation by Areas
(Andaman and Nicobar Is., Hakuyō Maru, 1929)

Area	Number of Hooks	Number of Fish Taken	Catch Rate
north of 9°	1,410	37	2.63
south of 9°	1,584	140	8.86

The catch rates are higher south of 9°, as is clear from Table 10, and the yellowfin run around 40 kg in weight, but north of 9° the catch rates are lower and the fish are somewhat larger.

We may summarize the foregoing data on the distribution of tunas and spearfishes in the various sea areas of the Indian Ocean region as follows:

1. The schools are most densely concentrated in the coastal waters of Sumatra and the Lesser Sundas.

2. Within Sumatran coastal waters fish are most abundant near and north of the Equator.

3. In the overall view one can detect a tendency for the distribution to be most concentrated during the northeast monsoon. Data on the southwest monsoon season are inadequate, but if the fish are more abundant during the northeast monsoon, it will represent a condition exactly opposite to that encountered in the Pacific areas.

4. Judging from the catch rates, the composition of the catch, and the size characteristics of the yellowfin, the distribution of the schools during the northeast monsoon is as follows:

i. The coastal waters of the Lesser Sundas are cut off from the coastal waters of Java to the west, while they are intimately related to the Banda Sea and Flores Sea area.

ii. The coastal waters of Java are cut off from the west in the vicinity of Sunda Strait, and the occurrence of fish in these waters is sparse.

iii. The population from the vicinity of Sunda Strait to the neighborhood of the Equator is different from that found north of the Equator.

iv. North of the Equator in the coastal waters of the Nicobar Is. the population appears to be different from that occurring north of the Nicobar Is.

v. It further appears that there is a distributional boundary in the vicinity of 9^{o}N.

5. The relationships between these populations and the ocean currents are extremely intimate (Figure 2).

6. Big-eyed tuna are generally more abundant in the low latitudes and scarcer in the high latitudes; the peak density of their occurrence is reached around December and thereafter their abundance gradually declines.

7. In contrast to the big-eyed tuna, the spearfishes tend to be least abundant around December, gradually increasing thereafter and reaching their peak around February.

III. Vertical Distribution

The study of the vertical distribution of the fishes of these populations is even more difficult than the study of their horizontal distribution.

According to Dr. Kishinouye, the vertical distribution of the tunas is as shown in Figure 3.

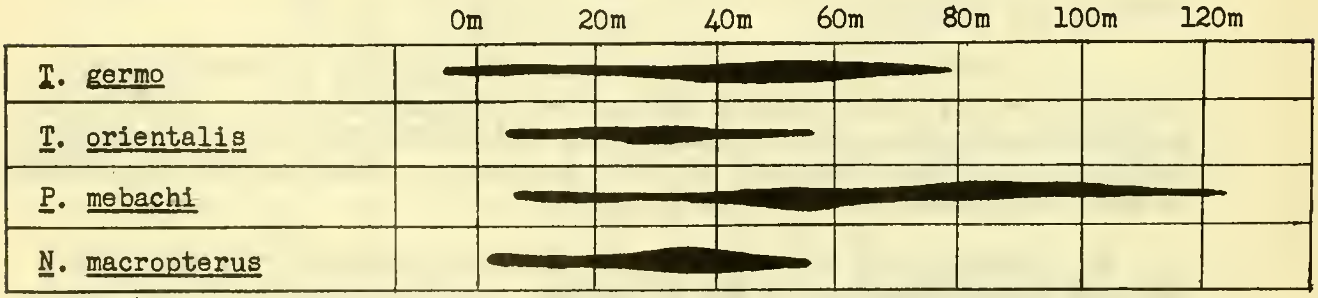


Figure 3 Vertical distribution of tunas

This indicates that the species which occurs at the greatest depths is the big-eyed tuna, followed by the albacore, and that the yellowfin lives in the shallowest levels. We have no results from any such study on the spearfishes, but they are known to be generally distributed in the shallow strata. The vertical distribution of these fishes differs between night and day, it being thought that they generally go deep during the day and swim at shallow levels at night.

The present author has shown, in the results of the surveys of the Shōnan Maru, that these fishes occur at far greater depths than was indicated by Dr. Kishinouye, however, these data were from the warm seas of the south while Dr. Kishinouye's observations were made in the coastal waters of Japan proper so the differences of environment must be fully taken into consideration.

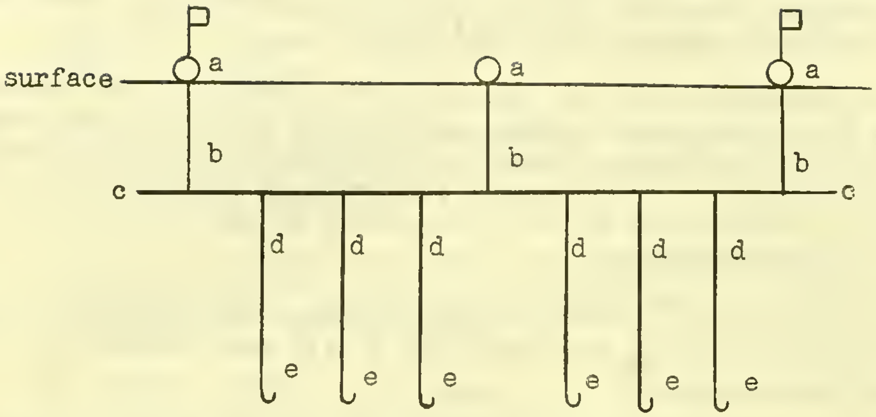
Our discussion of vertical distribution is, after all, based on the construction of the fishing gear, so I will here present a brief description of this gear.

In the longline gear in general use, as is shown in Figure 4, there are no floats attached to the branch lines. The gear used by the Shōnan Maru, as shown in Figure 4b, had floats attached to each branch line. The number and lengths of the branch lines and the lengths of the float lines are not uniform but vary as between regions and individuals. If we compare the two sets of gear in the figure, we see that the type used by the Shōnan Maru is always subject to one limit, that is, the hook cannot go any deeper than the float line plus the branch line (including the sekiyama and the wire leader), while the other gear has two limits, one when two floats are right together and the other when the trunk line is at full stretch, however, in any other case it is not easily possible to determine the depths at which the hooks are.

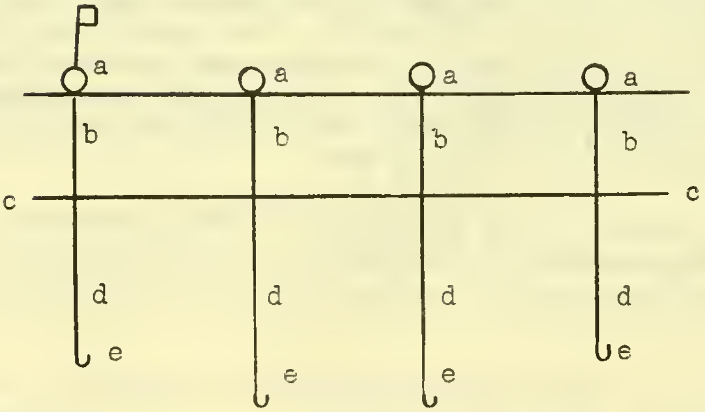
The results of the experimental fishing carried on in the waters east of Formosa were as follows:

Table 11 Catch at Various Depths (1935, Shōnan Maru)

Depth (m)	Yellowfin		Big-eyed		Spearfishes		Sharks		Number of Hooks
	No.	%	No.	%	No.	%	No.	%	
33	8	0.5	0	0.0	2	0.1	35	2.0	1,758
56	6	0.7	1	0.1	10	1.0	9	1.0	879
86	15	1.0	3	0.2	11	0.6	10	0.5	1,758



a - gear in general use



b - gear used by Shōnan Maru

a - floats d - branch lines
b - float lines e - hooks
c - trunk line

Figure 4 Construction of longlines

Table 12 Catch at Various Depths (1936, Shōnan Maru)

Depth (m)	Yellowfin		Big-eyed		Spearfishes		Sharks		Number of Hooks
	No.	%	No.	%	No.	%	No.	%	
60	22	1.0	5	0.2	38	1.8	42	1.9	2,160
80	28	1.3	5	0.2	11	0.5	9	0.4	2,160
100	32	1.5	2	0.1	10	0.5	1	0.0	2,160

The % shown in these tables is the ratio per 100 hooks. In addition to the catches indicated in Table 12 in 1936 two albacore were taken at 100 m.

Looking at these tables it appears that the deeper one goes the better the yellowfin catch is, while the big-eyed tuna tend to occur at somewhat lesser depths than the yellowfin. In general the fishing for the spearfishes is better at the shallow levels, and the sharks are taken in greatest numbers on the shortest branches.

In the survey made by the Shōnan Maru in the East Philippines Sea branch lines of 80m and 100m were used. As a result it was found that both for tunas and spearfishes (almost exclusively yellowfin and black marlin) the 100m lines fished somewhat better.

The results of investigations in the Celebes Sea were as follows:

Table 13 Catch at Various Depths (Celebes Sea, Shōnan Maru)

a. 1931

Depth (m)	45	68	91	129
Catch rate(%)	4.2	1.7	2.1	5.9

b. 1932

Depth	23	90	113	136	160
Catch rate(%)	3.9	7.3	4.7	5.1	6.0

c. 1934

(a) Eastern area (125° - 130°E)

Depth	Tunas Number	Tunas %	Spearfishes Number	Spearfishes %
45	9	2.5	11	3.1
76	53	7.6	28	3.9
106	47	6.5	11	0.6

(b) Celebes Sea area (west of 125°E)

	Tunas		Spearfishes	
Depth	Number	%	Number	%
45	65	6.25	26	2.50
76	182	8.76	36	1.72
106	205	9.86	20	0.95

It is regrettable that the data are not presented by species. The results from 1931 and 1932 show that there is a tendency for the good fishing depths to form two levels. These were 45m and 129m in 1931, and 90m and 160m in 1932.

In 1934 this tendency was not clear, but this is thought to have been due to a simplification of the gear. The 1934 results indicate a difference in the depths at which fishing was good as between the eastern sea area and the Celebes Sea area.

In any case, it is certain that the spearfishes occur in the shallower levels and the tunas in the deeper ones, and this fact holds true for all of the sea areas farther south.

Considered from the facts detailed above, the maximum depth at which these fishes occur is not yet known, however, it is thought that in the southern seas, at least, they occur at much greater depths than has been hitherto believed, and a certain number of fish are caught as far down as 160m. The depth at which the fish occur in the greatest abundance differs somewhat from area to area, but it is thought to be in general around the 100m level. Therefore it is believed that for fishing in the southern seas gear so constructed that the hooks are at the 100m level would be the most efficient.

IV. Food

These fishes are completely carnivorous and do not eat any vegetable food. It is doubtful whether or not they have any selectivity with regard to their food, and it is wondered whether they do not simply try eating anything that moves or shines in the water. An examination of their stomach contents reveals that they are truly miscellaneous, containing various juvenile fishes, crustaceans, squid, nautilus, and other mollusks, while even such things as jellyfish are frequently found.

There are, of course, differences depending on the size of the fish, the place, and the season, however, in general in the southern waters squid are the most commonly seen natural food, followed by small fishes which live around floating logs. Depending on the place, it is not at all unusual to find them feeding solely on crustaceans. These facts should not be interpreted as meaning that the tunas and spearfishes are particularly fond of these animals, but probably that they eat whatever is most plentiful and easiest to catch.

In the past it has been believed that these fishes do not feed at the bottom nor along cliffs, but yellowfin taken in the vicinity of the small islands in the eastern part of the Celebes Sea were sometimes found to have gravel in their stomachs. In such cases the food contains a good deal of crustaceans and small mollusks from which it appears that at some places these fishes hunt food along the bottom of the sea. No such phenomenon has as yet been observed in the case of the spearfishes. Considering the form of the jaws, this is very natural for it would probably be impossible for a marlin, with the two halves of its beak of such markedly unequal length, to hunt food on the bottom.

When we come to the large tunas and spearfishes, we find that they can easily swallow whole a skipjack of 10 pounds weight. From the position of such items in the stomach it appears that the prey is more often swallowed head first than tail first.

If we look at the fish which come out of tuna and spearfish stomachs, almost all of them have wounds on the body just posterior to the head. This may show that when the fish are feeding they first bite their prey from the side and kill it after which they swallow it. The fishes which are ingested into the stomach appear to be digested very rapidly, and only viscous liquid is found in the intestines, no solid matter being discoverable. An interesting thing is what happens to the skeletons of the fish which are swallowed. Cases are often encountered in which the flesh is completely digested and only a large quantity of bones remains in the stomachs. Since, as already mentioned, no solid matter can be found in the intestines, the skeletons must either dissolve completely in the stomachs or else they must be regurgitated. It is not yet known which actually occurs.

V. Reproduction

Almost nothing is known concerning the reproduction of these fishes. It is certain that they spawn in the open sea, that the eggs which they lay are very small, and that they are of the so-called pelagic type, which float on the surface of the sea. Since the eggs are extraordinarily small they hatch out in a short time; the parent fish make no particular effort to protect them. Newly-hatched larvae around 2 or 3 mm in length are already living as independent organisms. What follows is a brief account of what is known at present on this subject.

Areas which are known with some certainty to be spawning grounds of black tuna are the northeastern portion of the South China Sea, the Pacific coastal waters off northeastern Luzon, and the Bashi Strait. Of course this is not to say that these are the only spawning areas, and it is certain that there are other as yet unknown spawning grounds. As was explained in the section on distribution and migrations, the tuna appear in this area from the middle of March to early in June and spawning seems to occur chiefly in May. The catch in the early part of June includes many spent fish.

The author has previously obtained and reported ripe ovaries of this species. The eggs are extremely small, the diameter being 0.85 mm. The

ova contained in the ovaries of one fish amount to over one million (Figure 5).

On the coasts of Japan proper fish with conspicuously developed gonads are seen from June to July, and in August spawning is already finished. This being so, the tuna which migrate to the Japanese coasts and those which appear in Formosan waters may be considered to be clearly of different populations. With regard to the black tuna of Japan proper, Dr. Kishinouye recorded that he had never seen any completely ripe eggs, but that spawning probably took place off the Pacific coasts of Kyūshū and Honshū.

The smallest specimen collected up to the present time is one of 22 cm total length obtained by Dr. Kishinouye. Fish 25 cm long and weighing about 20 g are taken on hook and line in the summer on the coast of Miyazaki Prefecture, where they are known as imoshibi. Even smaller ones are taken in Kanagawa and Mie prefectures, where they are called kakinotane, abuko, or bintsu. By winter these fish attain a length of 40 cm, and in the summer of the following year they weigh 2 to 3 kg. It is thought that after three years have passed the fish become mature and begin to spawn. It appears that among the fish commonly caught those 5 to 7 years old predominate.

The smallest specimen collected in Formosan waters was about 40 cm long and it was collected in February. We have not yet been able to get any smaller examples.

Almost nothing is known of the spawning season and spawning ground of the albacore. They probably spawn in the open sea. The same is true of the big-eyed tuna.

The yellowfin is presumed to spawn around February in the southern part of the South China Sea. The reason is that among the fish which are landed around February at Takao specimens are occasionally seen with extraordinarily well-developed gonads. The spawning grounds are not limited to the South China Sea, however, and spawning probably takes place everywhere in the seas of Greater East Asia. Among these the Banda and Flores seas area is receiving particular attention, but there are as yet no data.

There used to be a cannery called the Sea-Food Cooperation [sic] at Zamboanga, and a man who worked there has reported that in the Sulu Sea area fish with ripe gonads were often taken.

Fish of around 40 cm body length generally inhabit the open sea where they either form solitary schools or school together with skipjack. They are occasionally taken in large set-nets in the waters east of Formosa.

Among the spearfishes the short-nosed marlin appears to spawn around December in an area centered about 150 miles east of Formosa, and some ripe ova of this species have been obtained. (Figure 5)

The spawning of the sailfish occurs over wide areas of the Pacific and the South China Sea and covers a rather long period of time with June as the peak. Around this time this species occurs densely in these sea areas, and mature and immature fish occur mixed together. It is interesting that spawning proceeds gradually as the fish become ripe, the males and females forming pairs and following each other around in the same way goldfish do. On this point they differ completely from such fishes as the herring. With herring the whole school becomes ripe, and spawning and fertilization are accomplished within an extremely short time. These spawning habits of the herring are the sort generally possessed by pelagic species and they make the reproductive activity most effective. It is very interesting then that the spearfishes which are the most markedly pelagic of fishes, have the habits described above. Since spawning habits of this type appear to be common to the fishes of the south in general, this is thought to be an important matter to consider with regard to the future of the southern fisheries.

The diameter of the eggs is from 0.8 mm to a little less than 1 mm, and the ovaries of a large individual contain over 1 million eggs.

The larval fish have a form altogether different from their parents, and their heads are armed with conspicuous spines. It is thought that these are for the purpose of increasing the surface area of the larvae, whose swimming powers are weak, in order to facilitate their floating. The smallest specimen which the author has been able to obtain to date is about 3 mm long, and it is thought to have been collected not too long after hatching, hardly any pigment having appeared on its body. Several specimens ranging from this size up to about 12 mm have been collected, but we have not as yet been able to collect any larger than that until we get up to the range of 140 mm to 260 mm, where we have obtained several specimens. (Figure 6)

As far as the true marlin [M. mitsukurii] is concerned, we have recently had two opportunities to collect ripe eggs and can therefore make some conjectures about its spawning season in Formosan waters (the South China Sea). Both of the specimens were landed at the Takao fish market in May, one in 1941 and the other in 1943. Unfortunately it is not clear just where these fish were taken, but in any case it can be considered fairly certain that this species spawns about May.

For the black marlin [M. mazara] we have ripe eggs collected in the East Philippines Sea in May so it can be thought that they probably spawn around that month. (Figure 5)

For the white marlin [M. marlina] we have as yet no concrete data from which to deduce their spawning season and spawning grounds, but it is wondered whether they may not spawn in April and May in the area from Annam to Hainan I.

As indicated above, our knowledge of the tunas and spearfishes is extremely poor. In the near future, when the fisheries of Greater East Asia come to be seriously developed, many new facts will probably come to

light. The author's personal opinion is that, whatever the present problems may be, it is difficult to expect much in the future for the fisheries of Greater East Asia from coastal and bottom fisheries, while it is thought that much can be expected from the tunas and spearfishes. For this reason it is believed that extremely important significance may attach to the clarification of the habits of these fishes.

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Description of Figures Not Reproduced in Translation

Figure 1a Photograph of a leaping marlin
Figure 1b Photograph of the landing of a shark
Figure 1c Photograph of the stowing of a large tuna
Figure 5a Sketch of a ripe ovum of M. mazara (x30)
b. Sketch of ripe ovum of short-nosed marlin [T. angustirostris] (x30)
c Sketch of ovum of sailfish (x30)
d Sketch of ripe ovum of black tuna (x35)
Figure 6a Larval sailfish (about 3mm long)
b Juvenile sailfish (about 12mm long)
c Juvenile sailfish (about 140mm long)
Unnumbered - Boating a harpooned marlin [photograph]